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A STUDY OF SURGICAL MANAGEMENT OF RIB FRACTURES FOLLOWING TRAUMA PATIENTS IN OUR INSTITUTION

Orthopaedics

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ABSTRACT

Background: Surgical management of chest wall injuries has received increasing attention in recent years. The aim of this thesis was to study the mechanism of injury (MOI) in relation to chest wall injury patterns and short- and long-term outcome of surgery in patients with multiple rib fractures and unstable thoracic cage injuries.
Methods: Paper I is a retrospective study (n=211) of the association of MOI and injury patterns in patients operated for acute chest wall injuries. Paper II is a prospective longitudinal study (n=54) of the long-term outcome of surgery in patients with multiple rib fractures and flail chest. Paper III is a cross-sectional study (n=37) of the use of CT-lung volume estimation as a marker for lung function in patients operated for flail chest. Paper IV is a prospective controlled study (n=139) of the short- and long-term outcome of surgery in patients with unstable thoracic cage injuries.
Results: The MOI differs according to age and is associated with different chest wall injury patterns. Lateral and posterior flail segments are the most commonly seen. Symptoms of pain, lung function and Quality of Life (QoL), improve during the first post-operative year. CT-lung volume estimates increase significantly from pre- operative values to post-operative values and there is a high correlation between post-operative CT-lung volume and lung function. Surgery for unstable thoracic cage injuries does not decrease the need for mechanical ventilation. However, surgically managed with rib plating patients have a decreased incidence of pneumonia (17% vs. 36%, p=0.013) and less pain (29% vs. 57%, p<0.05) the first months' post trauma. Patients operated without thoracotomy have a better residual lung function and lung volume. A gradual improvement in patient symptoms was seen and after one year there was no difference in symptoms, function or QoL between surgically managed with rib plating and conservatively managed patients.
Conclusions: The MOI influences rib fracture pattern and associated injuries. Lung volume estimated by CT can be used as a marker for lung function. Surgery for unstable thoracic cage injuries decreases the incidence of pneumonia and reduces pain. Patients continue to improve gradually and no difference can be seen between the surgically managed with rib plating and conservatively managed patients one year post trauma.

KEYWORDS

Mechanism of Injury; Rib Fracture; Flail chest; Surgery; Mechanical Ventilator; Lung Function; Pain; Quality of Life

INTRODUCTION

Trauma is a major global health issue and responsible for causing injury in tens of millions of people that result in long-term disability and over five million deaths annually. In Sweden, despite having the second lowest incidence of deaths due to road traffic accidents in Europe, [1] trauma was responsible for hospitalizing over 109,000 injured people and causing, 984 deaths in 2017. Trauma is the sixth leading cause of death in all age groups and the leading cause of death in people aged 10–44 years. Although blunt trauma is the dominating mechanism of injury (MOI) in Sweden, occurring in approximately 90% of cases, the incidence of penetrating injuries is on the rise.[2]

Trauma to the thorax causing injuries to the chest wall, lungs and cardiovascular system, accounts for approximately 23–37% of trauma- associated mortality.[3] Although traumatic brain injury (TBI) and exsanguination are the most common causes of death, respiratory failure is a contributing factor in 17% of patients with blunt trauma.

Rib fractures are common and occur in approximately 9-12% of all trauma patients and in 34–39% of patients with thoracic trauma seeking medical attention. Isolated rib fractures are seen in 6–13% of cases with thoracic trauma. Rib fractures are commonly associated with both intra- and extra-thoracic injuries. Common intra-thoracic injuries include pneumothorax in 29–37%, haemothorax in 21–32%,[4] lung contusion in 17–31%, lung laceration in 1.6–5.3%, cardiac injury in 0.7–1.3%, great vessel injury in 1.5–2%, 18 and diaphragmatic injury in 1.2–3% of cases.[4] The majority of patients with thoracic trauma, especially blunt trauma, can be treated conservatively.

Unstable thoracic cage injuries have been described using various terms. In 1945, Hagen described "stove in chest", a term used for unstable thoracic cage injuries with chest wall deformity. In 1949, Heroy used the term "steering wheel injuries" in patients admitted due to blunt thoracic trauma.[5] The MOI was head-on collision automobile accidents without restraints causing bilateral anterior rib fractures. Paradoxical respiration was described in 14% of the patients, and defined as "a movement of the thoracic cage in a direction opposite to that seen in the normal".[5] The term flail chest (FC) was later coined by Cohen in 1955, and has been used to describe both the paradoxical breathing associated with chest wall instability and the anatomical condition of multiple consecutive rib fractures. The currently widely used definition, according to the Abbreviated Injury Scale (AIS) 2008, defines FC as an anatomical condition that requires three or more adjacent ribs, fractured in more than one location in order to produce a free- floating segment, and/or paradoxical chest movement. Paradoxical breathing is not, however, seen in all cases of anatomical FC, but is classically described in "steering wheel injuries" as these produce more anterior flail segments that are easier to visualize.

AIMS AND OBJECTIVE

The overall aim of this thesis was to study the role of surgery in the management of rib fractures and its impact on clinical outcome.

The specific aims were to:

I. Study the mechanism of injury (MOI), injury patterns and associated injuries in patients with chest wall trauma undergoing surgery.

II. Investigate the long-term patient outcomes associated with pain, physical function, lung function and quality of life (QoL) after surgical stabilization of chest wall injuries.

III. Evaluate the use of pre- and post-operative computed tomography (CT) images of the thorax in order to estimate and compare pre- and post-operative lung volumes and the use of CT as a marker for lung function.

IV. Compare short-term and long-term clinical outcomes in patients with unstable thoracic cage injuries treated surgically with rib plating compared to those treated conservatively.

PATIENTS AND METHODS

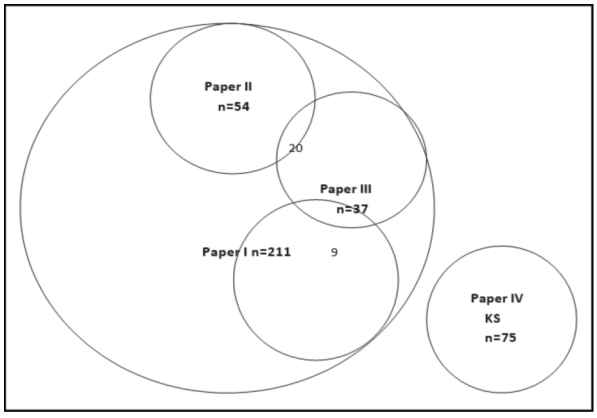
Patients included in the studies (Table 2) were recruited from Sahlgrenska University Hospital (SU) (papers I–IV) and Karolinska University Hospital (KS) (Paper IV). Patients from SU were managed surgically with rib plating, whereas patients from KS were managed conservatively.

Table: Main Research Questions, Study Design And Outcome Measures In Papers I-IV.

Paper	Main Research Question	Study Design	Patients	Outcome Measures
I	Mechanism of injury and injury patterns in patients undergoing chest wall surgery	Retrospective	n=211	Mechanism of Injury Chest Wall Injury Patterns Associated Injuries

II	Long-term effects of chest wall surgery	Prospective, Longitudinal	n=54	Complication Mortality Pain Lung Function Breathing Movement Range of Motion Disability QoL
III	CT-lung volume estimation as a marker of lung function in patients with flail chest	Cross-sectional	n=37	CT-Lung Volume Lung Function Pain Range of Motion Breathing Movement
IV	Need of mechanical ventilator in surgically managed with rib plating vs. conservatively managed patients with unstable thoracic cage injuries	Prospective, Controlled	n=139 Clinical follow-up n=92	LOS on ventilator, ICU and hospital Complication Mortality Pain Range of Motion Shoulder Function Breathing Movement Lung Function CT-Lung Volume Disability Physical activity Return to Work QoL

Data from 211 trauma patients treated at SU during the period September 2010 to September 2017 and from 75 patients treated at KS during the period June 2014 to June 2017 were included in this thesis. All patients from SU in papers II–IV were included in Paper I. Some patients were included in three of the papers, twenty patients in papers I–III and nine patients in papers I, III and IV. Patients in papers II and IV did not overlap.



Distribution of patients in the studies in papers I–IV. KS=Karolinska University Hospital Solna.

METHODS

Patient And Trauma Demographics

Patient and trauma demographics were collected from studied patients. Injury severity scores were used to assess trauma burden and the severity of injury. Abbreviated Injury Scales (AIS) for the different injuries were estimated (1– 6)23 and ISS (1–75)32 and New Injury Severity Score (NISS) (1–75)94 were calculated.

Included patients were offered routine analgesia with paracetamol, Non- Steroidal Anti-Inflammatory Drugs (NSAID), opioids and TEDA. Some surgically managed with rib plating patients received an inter-pleural catheter per-operatively for administration of local analgesia. Low-molecular weight heparin was given subcutaneously as thrombotic prophylaxis in all trauma patients, as routine.

RESULTS

Our study showed that the most common MOIs were falls and traffic accidents (Table 6). All but one patient suffered blunt trauma. The MOI differed according to age, with traffic accidents being the most common MOI (62%) in patients aged 15–44 years, and falls being the most common MOI (59%) in patients aged >64 years. ISS and NISS varied according to MOI, rather than age group, where the highest values were seen in traffic accidents, especially MVC other and PVA. Crush injuries also generated high ISS and NISS values. Sternal fractures were present in 43% of patients with bilateral injuries compared to 9.7% of patients with unilateral injuries. Fractures to clavicles (21%) and scapula (24%) were equally distributed between patients with unilateral and bilateral injuries. Per-operative assessment of intra-thoracic injuries in patients undergoing thoracotomy in conjunction with ORIF showed that CT underdiagnosed injuries, with a calculated sensitivity of 68% for pulmonary contusion, 29% for lung laceration and 14% for diaphragmatic injury. In fact, per-operatively 81% of patients were found to have pulmonary contusion, 62% lung laceration and 18% diaphragmatic injury.

We found in patients' QoL measured by EQ-5D-3L showed median index values increasing progressively over time, with the greatest improvement occurring between 6 weeks and 3 months (Fig. 15). There was a significant decrease in the proportion of patients suffering problems with mobility (-27%, p=0.022), self-care (-36%, p=0.0005), usual activities (-55%, p=0.0001) and pain or discomfort (-27%, p=0.035) after one year, compared to 6 weeks post- operatively. There was no significant improvement in symptoms of anxiety or depression over time. Median VAS, measuring QoL, improved from 60% (20–96) at 6 weeks to 76% (40–97) at 3 months to 80% (20–100) at 6 months to 90% (30–100) after one year (p<0.0001). Pre-operative CT findings were compared to CT at follow-up in 37 patients who had undergone stabilizing surgery for flail chest. Median CIS was 4.0 (3–4) and LIS was 2.0 (0–4). None of the included patients had undergone resection of lung tissue in conjunction with ORIF. The post-operative CT was performed at the earliest six months post-operatively and the median time for follow-up was 3.9 (0.5–5.6) years post trauma.

We showed that the median CT-lung volume increased significantly from 3.51 l (1.50 – 6.05) on pre-operative CT to 5.59 l (2.18 – 7.78) on post-operative CT (p<0.0001). This improvement was seen regardless of whether or not patients had pneumothorax, lung contusions or were intubated at initial CT. Manual measurements were performed twice per patient (n=21 pre-operatively and n=19 post-operatively) and showed a median difference of 0.03 l (0–0.29) between measurements, which was not statistically significant (p=0.303). Lung volumes estimated on CT comparing initial CT with CT six months post trauma, improved significantly in all subgroups of patients. However, the increase in CT-volume was significantly greater in the patients stabilized without a thoracotomy than in patients operated with a thoracotomy (3.1 vs. 2.4, p=0.040) or in patients treated conservatively (3.1 vs. 2.3, p=0.028).

GENERAL DISCUSSION

The aim of this thesis was to address the issue of surgical management of rib fractures, through studying the association of MOI with different chest wall injury patterns, evaluating radiological models for prediction of lung function and assessing short- and long-term outcomes of surgery.

Under-triage of the elderly is especially common, despite research showing the increased risk of mortality in the elderly trauma patient with rib fractures.[6] Since the possibility of managing rib fractures surgically is still quite novel many clinicians that care for the elderly patient with chest wall trauma may not be aware of the treatment possibilities available. As a result, the focus of care may be on the underlying medical conditions, which are of importance. However, the patient is unlikely to be admitted as a trauma alert and will therefore not undergo a CT but instead most likely a simple CXR to diagnose pneumothorax and pleural fluid. Considering the development of modern treatment of chest wall injuries, it is inappropriate to perform a radiological examination that will not be able to rule out neither intra-thoracic injuries nor provide the clinician with an overview of the chest wall injury. In fact, the elderly trauma patient may have more to gain from surgical stabilization of chest wall injuries than the young patient, as this decreases the risk of pneumonia. Although the elderly patient may be frail at the time of the trauma with an increased risk of mortality, the patient may respond and benefit from appropriate resuscitation but require a higher level of care to survive.[7] Therefore, it is important to be proactive in the resuscitation and management of the elderly trauma patient in order to produce the best possible outcome. There are of course patients where interventions should be limited. But complications due to under-resuscitation and neglect should not be used as a reason for conservative management.

The indication for surgery in papers I-II was multiple rib fractures and unstable thoracic cage injuries, whereas in papers III-IV it was solely unstable thoracic cage injuries. The indication for surgery of chest wall injuries has been debated and current guidelines mainly support surgery for FC as this may decrease the LOS on mechanical ventilator,

and the incidence of pneumonia and mortality.[8] Studies focusing on patients with FC and pulmonary contusions have found no benefit with surgery. However, the basis for these studies is a diagnosis of pulmonary contusion on initial CT. Since contusions often develop over time and are under diagnosed on initial CT,[9] it is possible that these studies only included patients with the most severe lung injuries, requiring mechanical ventilation. Most studies have excluded patients with severe TBI, often defined as a decreased level of consciousness or AIS>3, as they require longer time on mechanical ventilator, While, it may be argued that optimizing the patients' respiration will be positive for the outcome. Currently there is no data to support a decreased time spent on mechanical ventilator with surgery of FC in patients with severe TBI. One may hypothesize that if the patient is expected to remain on mechanical ventilator in the ICU for at least 14 days, during which time callus forms, then surgery may be unnecessary.

Previous studies on the surgical management of FC have mainly focused on managing respiratory insufficiency in order to minimize the need for mechanical ventilation and reduce complications like tracheostomy, pneumonia and mortality.[10] Considering the heterogeneity in trauma patients it is possible that they can be divided into several subgroups, where according to pre-existing lung disease, higher injury burden and associated injuries they will require mechanical ventilation to different degrees, regardless of surgery. Voggenreiter et al. attempted such a study on the outcome of surgery in patients with or without pulmonary contusions.[11] However, the subgroups were too small for all the necessary statistical analyses to be done. The challenge with performing a study with subgroup analyses is the need for including large data material. In order to do so a multi-center study will need to be planned. But before this can be undertaken there needs to be an internationally recognized system for classifying chest wall injuries and flail segments, and the operative technique needs to be more standardized. Any operation may not be better than no operation.

CONCLUSIONS

- Distinctive chest wall injury patterns can be identified in thoracic trauma as a result of different mechanisms of injury, and is associated with different probabilities of extra- thoracic injuries.
- Patients managed with surgical plate fixation for multiple rib fractures recover gradually with improvement in pain, physical function, lung function and QoL, during the first post-operative year.
- Estimates of lung volume on CT increase significantly when comparing immediate post-trauma CT with CT after six months, and can be used as a marker for lung function.
- No difference in LOS on mechanical ventilator and in ICU is seen between surgically managed with rib plating and conservatively managed patients, despite surgically managed with rib plating patients having more severe thoracic injuries.
- Patients managed surgically with rib plating for unstable thoracic cage injuries have less pneumonia and experience less pain and discomfort during the first months' after trauma, compared to conservatively managed patients.
- There is a considerable difference in long-term outcome between patients managed surgically with rib plating compared to conservatively for unstable thoracic cage injuries, one year after trauma.

Table: Mechanism Of Injury Distribution In 211 Trauma Patients.

Main MOI	n (%)	Specific MOI	n (%)
Falls	93 (44.1%)	Fall from same level	51 (24.2%)
		Fall from height	42 (19.9%)
Traffic accidents	93 (44.1%)	MVC other	20 (9.5%)
		MVC single	19 (9.0%)
		PVA	17 (8.1%)
		Motorcycle accident	21 (10.0%)
		Bicycle accident	16 (7.6%)
Other accidents	25 (11.8%)	Crush injury	3 (1.4%)
		Miscellaneous accidents	13 (6.2%)
		Assault	9 (4.3%)

Table: Main Indication For Surgery Of Acute Chest Wall Injuries In 211 Trauma Patients.

Main indication for Surgery	Patients (n, %)
Flail chest	184 (87.2%)
Multiple rib fractures and pain	11 (5.2%)
Severely dislocated rib fractures affecting internal organs	9 (4.3%)
Rib fractures and lung herniation	3 (1.4%)
Rib fractures with chest wall deformity	2 (0.9%)
Rib fractures with massive haemothorax and diaphragmatic injury	1 (0.5%)
Rib fractures with continuous air leakage	1 (0.5%)

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